# FIRST RESULTS FROM A *XMM-NEWTON* SURVEY OF A DISTANCE-LIMITED (D<22 MPC) SAMPLE OF SEYFERT GALAXIES: I- THE AGNS

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## Abstract

We report here preliminary results from a survey of nearby Seyfert galaxies using the EPIC CCDs on board *XMM-Newton*. The total sample consists of 28 Seyfert galaxies, and constitute a well-defined, complete ($B_T \lesssim 12.5$ mag), and volume-limited (D<22 Mpc) sample of Seyfert galaxies in the northern ($\delta > 0°$) hemisphere. The survey has been initiated in June, 2001, and we report here the results for the 6 objects analyzed so far, namely: NGC3185, NGC3486, NGC3941, NGC4138, NGC4565, and NGC5033. The main goal of this survey is to obtain a better and unbiased understanding of the "typical" Seyfert X-ray spectrum (e.g. the distribution of their absorption column density) in the local Universe. This is crucial to verify the predictions and, thus, to validate unified models, and is a fundamental parameter of synthesis models for the X-ray background. A companion poster (paper II: L. Foschini et al., these proceedings) illustrates how this survey will also allow a comprehensive spectral study of the brightest (highest-luminosity) off-nuclear sources in the galaxies.

Key words: Galaxies: active - X-rays: galaxies - Mission: XMM-Newton

## 1. Framework

Important emphasis in research on Active Galactic Nuclei (AGNs) in recent years has been in the area of unified models (e.g. Antonucci 1993). These models try to explain the observed differences between broad (Seyfert 1's-like) and narrow (Seyfert 2's-like) optical emission-line AGNs by invoking obscuration (from an optically and geometrically thick torus) and viewing angle effects rather than intrinsic physical differences. A privileged energy band for such studies is the hard (E> 2 keV) X-ray band, where continuum photons are less affected by absorption and where imprinted features (e.g. the photoelectric absorption cut-off, the fluorescent FeK line) allow to probe the physics of the AGNs' nuclear regions, and their surroundings.

While there is increasing consensus on the validity of these models, at least for those that unify nearby "classical" Seyferts, questions remain on the "typical" Seyfert galaxy X-ray spectrum. This is particularly true for lower-luminosity objects and for the detailed relationship between their X-ray versus optical appearance and classification. In particular, several open questions remain, such as whether the X-ray spectra of all nearby Seyferts are consistent with unified models and whether the X-ray spectra of low-luminosity Seyferts are consistent with that of higher luminosity ones. Also, precise knowledge of the distribution of column densities and the geometry of the putative molecular torus, of the origin of FeK emission lines, and of the shape of the X-ray luminosity function of local Seyfert galaxies once extended to its fainter end, is still lacking.

Answers to the above questions are also crucial to put tighter constraints on synthesis models of the XRB and to understand the evolution of "Seyfert-like" AGNs with cosmic time (e.g. Comastri et al. 1995, Gilli et al. 2000). These models usually assume the validity of unified models and suggest that a combination of unabsorbed (Seyfert 1-type) and absorbed (Seyfert 2-type) AGNs may account for most of the X-ray background (XRB). But in fact, major uncertainties remain in the assumed $N_{\rm H}$ distributions, luminosity functions of both types of objects and their evolution with cosmic time.

The definition of the spectral properties of a complete and, *bona fide*, unbiased sample of nearby Seyfert galaxies is, thus, desired to address both the issues of unified models of AGNs and synthesis models of the XRB.

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## 2. Previous and Current Studies

Hard X-ray samples of nearby Seyfert galaxies available to date (e.g. from *GINGA*, *ASCA* and *BeppoSAX*; Smith & Done 1996, Turner et al. 1998, Bassani et al. 199) have been essentially biased towards the most X-ray luminous, and less absorbed AGNs[1]. Moreover, the poor spatial resolution of the pre-*Chandra* and pre-*XMM-Newton* telescopes left unresolved issues such as a proper estimate of stellar/starburst processes and/or X-ray binaries contributions to the total X-ray emission of low-luminosity ($L_{2-10\mathrm{keV}} \lesssim 10^{40}$erg/s) Seyfert galaxies. Significant improvements have been obtained by Ho et al. (2001) using the ACIS CCDs on board *Chandra*, who can address for the first time the X-ray properties of LLAGNs (with 2-10 keV luminosities ranging from less than $10^{38}$ to $10^{41}$ erg/s) in nearby Seyferts, LINERs and LINERs/HII transition nuclei. These authors detected a compact, pointlike nuclear source in ∼62% of their initial sample of 24 (out of 41) nearby galaxies. However, the brief "snapshots" exposures used in the Chandra survey will make it difficult to obtain detailed spectral information at energies greater than 2 keV.

Given the above arguments, we have initiated an *XMM-Newton* X-ray survey of all known northern Seyfert galaxies with D<22 Mpc using the Revised-Ames Catalog of Bright Galaxies (Sandage & Tamman 1981) spectroscopically classified by Ho, Filippenko & Sargent (1997) according the classical definition of Seyfert galaxies (Veilleux & Osterbrock, 1987). The final sample contains 28 galaxies (see Table 1) and is the deepest and most complete local sample of Seyfert galaxies. The goal of this survey is to obtain a better, and unbiased, understanding of their "typical" X-ray spectrum. This high-throughput (especially for energies >2 keV) *XMM-Newton* survey is complementary to the arcsecond-resolution *Chandra* survey performed by L. Ho, E.D. Feigelson, and collaborators.

## 3. The *XMM-Newton* Sample

Our team has been awarded ∼ 250 ks of EPIC guarantee time, and exposures of 5, 10, 15 and 20 ks (with a typical value of 10 ks) were requested in order to obtain at least ∼ 1000 source counts[2].

To date, observations have been performed for about half of the galaxies, and data are available for 6 of them. Here we report on the preliminary results obtained for this subsample. The data were processed and screened with the Science Analysis Software (SAS; version 5.2) using standard procedures. The latest known calibration files and response matrices released by the EPIC team have been used. Data from MOS1/2 and PN were combined in the spectral analysis.

[1] But see the pioneering works by Maiolino et al. (1998) and Risaliti, Maiolino & Salvati (1999), and references therein.

[2] Expected count-rates were obtained from the observed 2-10 keV fluxes from Polletta et al. (1996) and Serlemitsos et al. (1997) and, when not available, from the $L_{2-10\mathrm{keV}}$-$L_{H_\alpha}$ correlation of Serlemitsos et al. (1997).

*Table 1. Distance-Limited (D<22 Mpc) Sample of Seyfert Galaxies*

| NGC Galaxy | Distance (Mpc) | B (mag) | Seyfert Type |
|---|---|---|---|
| 3031 | 1.4 | 7.89 | S1.5 |
| 4395 | 3.6 | 10.64 | S1.8 |
| 4258 | 6.8 | 9.10 | S1.9 |
| 3486 | 7.4 | 11.05 | S2 |
| 5194 | 7.7 | 8.96 | S2 |
| 1058 | 9.1 | 11.82 | S2 |
| 4565 | 9.7 | 10.42 | S1.9 |
| 4725 | 12.4 | 10.11 | S2 |
| 2685 | 16.2 | 12.12 | S2 |
| 4168 | 16.8 | 12.11 | S1.9 |
| 4388 | 16.8 | 11.76 | S1.9 |
| 4472 | 16.8 | 9.37 | S2 |
| 4477 | 16.8 | 11.38 | S2 |
| 4501 | 16.8 | 10.36 | S1.9 |
| 4579 | 16.8 | 10.48 | S1.9 |
| 4639 | 16.8 | 12.24 | S1.0 |
| 4698 | 16.8 | 11.46 | S2 |
| 3982 | 17.0 | 11.78 | S1.9 |
| 4051 | 17.0 | 10.83 | S1.2 |
| 4138 | 17.0 | 12.16 | S1.9 |
| 5033 | 18.7 | 10.75 | S1.5 |
| 3941 | 18.9 | 11.25 | S2 |
| 676 | 19.5 | 10.50 | S2 |
| 4151 | 20.3 | 11.50 | S1.5 |
| 3079 | 20.4 | 11.54 | S2 |
| 3227 | 20.6 | 11.10 | S1.5 |
| 3185 | 21.3 | 12.99 | S2 |
| 5273 | 21.3 | 12.44 | S1.5 |

## 4. Preliminary Results

Two of the earliest observations (NGC5033 and NGC3941) suffer from contamination by soft-proton flares which increase significantly the background (see Fig. 1, left panel) and, thereby, complicate/limit the scientific results. Nevertheless, examination of the images in Fig. 1 and 2 clearly illustrate the capabilites of this survey. Despite the short exposures, we are able to detect and distinguish the nuclei from the off-nuclear sources in the galaxies. The high throughput also allows us to perform a detailed spectral analysis of most sources. Three examples of such spectra are shown in Fig. 3. In these spectra, MOS1/2 and PN data were fitted simultaneously and with simple models (a single absorbed power-law for NGC5033 and NGC4565, and an absorbed plus scattered power-law for NGC4138) to illustrate the statistics available, as well as to high-

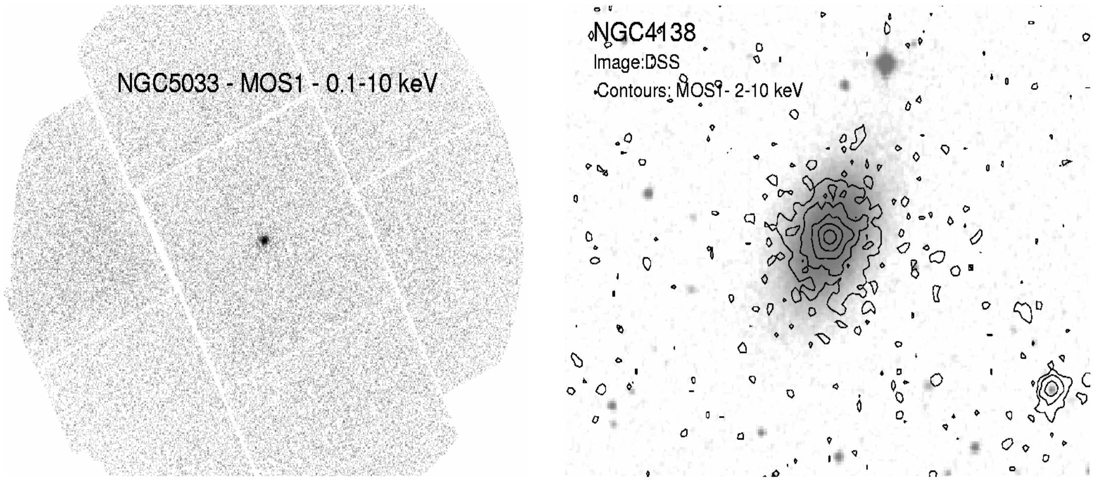


*Figure 1. (Left panel) MOS1 0.1-10 keV image of NGC5033. Despite the fact that this observation was contaminated by soft-proton flares (as demonstrated by the high background level), the source is clearly detected. (Right panel) MOS1 emission contours between 2-10 keV overlaid on the DSS image for NGC4138. These images illustrate well the cases where the sources are relatively bright, i.e. with* $F_{2-10\rm keV} \gtrsim 10^{-12}$ *erg cm*$^{-2}$ *s*$^{-1}$.

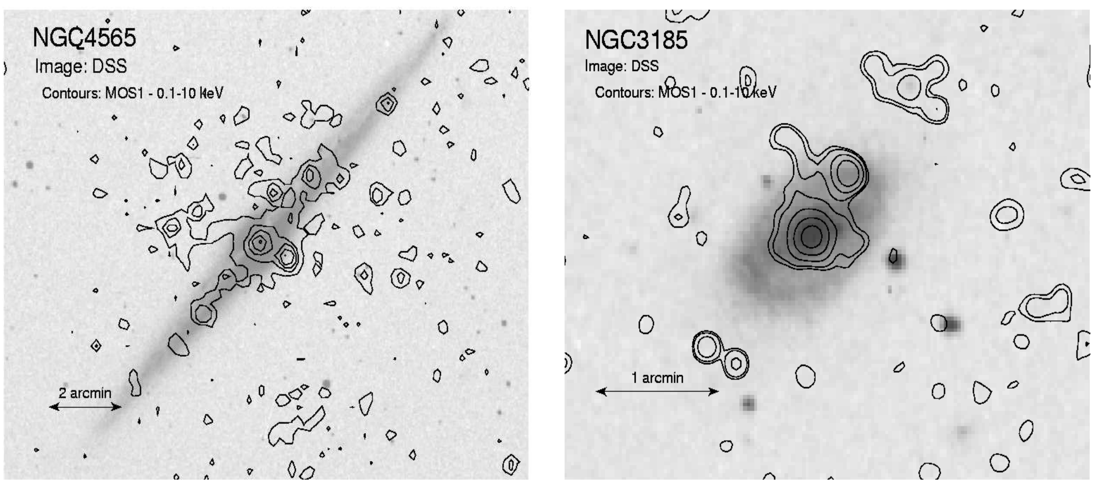


*Figure 2.* MOS1 (0.1-10 keV) contours overlaid on the DSS plates images of NGC4565 (Left) and NGC3185 (Right).

light the FeK features in the residuals for NGC5033 and NGC4138.

Preliminary spectral fits of the nuclear sources are summarized in Table 2. A discussion of the results in terms of "sample properties" is clearly premature here and will be presented in a forthcoming paper once other observations will be available. Nevertheless, these early results highlight the importance of this *XMM-Newton* survey. They confirm in fact that we shall be able to measure for the first time with good precision the absorption column densities, the spectral shapes, the soft (0.5-2 keV) and hard (2-10 keV) fluxes/luminosities, and also the FeK line parameters (at least for the brightest targets) for a significant number of Seyferts with luminosities down to $\sim 10^{39}$erg/s. We can also stress here some source-by-source interesting results that came out from this early analysis: i) the detection of an FeK line in NGC5033 and NGC4138 with EW$\sim$100-200 eV; ii) the detection of an absorbed component in NGC4138 and, possibly, in NGC3486; iii) the evidence of extended soft X-ray emission in NGC4138 and NGC4565, and iv) the presence of luminous off-nuclear sources in 4 out of 6 galaxies[3].

Last but not least, data from this survey will also be used to extend the spectroscopic survey of serendipitous sources initiated by Piconcelli et al. (these proceedings). In total, we expect that $\gtrsim 20$ serendipitous sources should be detected with EPIC in hard (2-10 keV) X-rays and give enough photons for a proper spectral analysis (see Piconcelli et al. for more details).

[3] See the companion paper by Foschini et al. (these proceedings) which illustrates well the capabilities of this survey to the study of ultraluminous X-ray sources in nearby galaxies.

*Table 2. Nuclear hard X-ray properties*

| Name | Sey Type | Exp. (ks) | $N_{\rm H}$ $\rm cm^{-2}$ | $\Gamma_{\rm 2-10keV}$ | $\rm F_{2-10keV}$ $\times10^{-14}$cgs | $\rm L_{2-10keV}$ $\times10^{39}$ erg/s | X-ray Class* |
|---|---|---|---|---|---|---|---|
| NGC3185 | S2 | 13 | $\equiv N_{\rm Gal}$ | 2.1±0.4 | 1.4 | 0.9 | I |
| NGC3486 | S2 | 5.5 | $>10^{23}$ | 2.2±0.3 | 5 | >1 | II-III |
| NGC3941 | S2 | 7 | $\equiv N_{\rm Gal}$ | 2.3±0.4 | 2 | 0.7 | II-III |
| NGC4138 | S1.9 | 14 | $8.2\pm0.7\times10^{22}$ | 1.6±0.1 | 500 | 400 | I |
| NGC4565 | S1.9 | 14 | $\equiv N_{\rm Gal}$ | 1.7±0.2 | 20 | 15 | II |
| NGC5033 | S1.5 | 7.5 | $\equiv N_{\rm Gal}$ | 1.7±0.2 | 280 | 150 | I |

*X-ray morphology class following the criteria given in Ho et al. (2001). This classification indicates 4 classes of X-ray sources where (I) the nucleus dominates the total X-ray emission; (II) the nucleus is comparable in brightness to off-nuclear sources in the galaxy; (III) the nucleus is embedded in diffuse emission; and (IV) the nucleus is absent.

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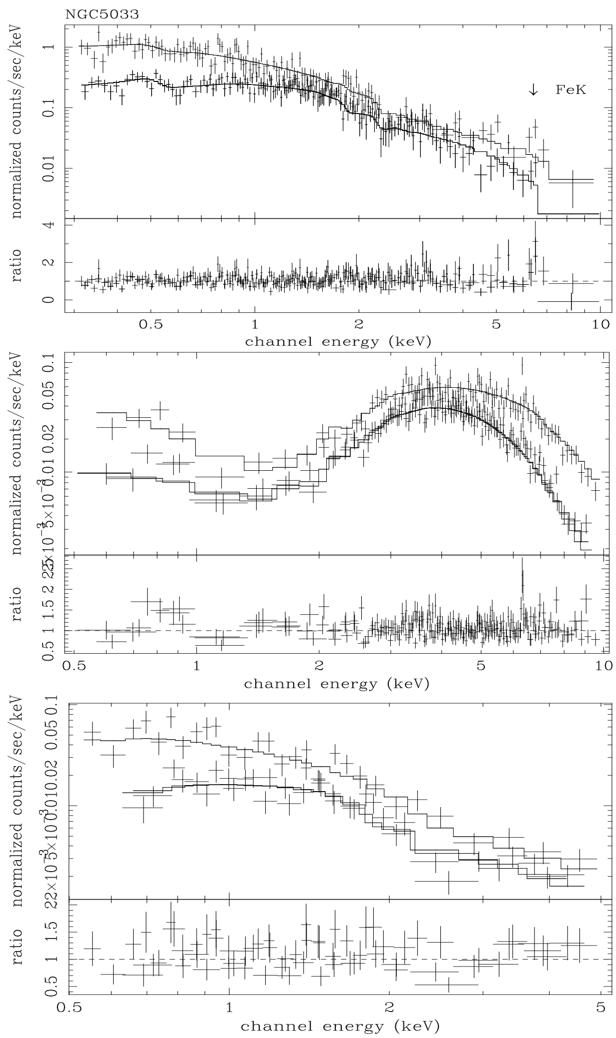


*Figure 3. MOS and PN spectra of NGC5033 (top), NGC4138 (middle) and NGC4565 (bottom). The models used are a single absorbed power-law model for NGC5033 and NGC4565, and an absorbed plus scattered component for NGC4138. Residuals are plotted in the form of data to model ratios. FeK lines are clearly detected in NGC5033 and NGC4138. These spectra illustrate well the kind of spectra we expect from this survey.*